Lake Okeechobee Water Level Management Using Climate-Based Operational Rules

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Abstract

Developed by the South Florida Water Management District in coordination with the Jacksonville District, the new Lake Okeechobee Regulation Schedule, WSE, Water Supply and Environment, was implemented in July 2000. In addition to using current lake conditions and tributary hydrologic conditions, the WSE schedule incorporates seasonal and multi-seasonal climate outlooks. The schedule's operational flexibility allows adjustments to be made in the timing and magnitude of Lake Okeechobee regulatory flows based on extended meteorological conditions and climate outlooks. This innovative approach to water level management has permitted water managers to successfully address South Florida's difficult water resource needs.

Introduction

Lake Okeechobee and its watershed are key components of south Florida's Kissimmee-Okeechobee-Everglades ecosystem, which extends from the headwaters of the Kissimmee River in the north to Florida Bay in the south. Lake Okeechobee is the "liquid heart" of South Florida. It is a large, shallow lake with a surface area of 730 square miles with an average depth of 9 feet (2.7 meters). It is the second-largest freshwater lake in the continental United States, second only to Lake Michigan. Lake Okeechobee's drainage basin covers more than 4,600 square miles (11,913 km2). It is home to one of the nation's prized bass and speckled perch fisheries, as well as an economically important commercial fishery. At the same time, it provides habitat for a wide variety of wading birds, migratory waterfowl, and the federally endangered Everglades Snail Kite. Lake Okeechobee also is a source of drinking water for lakeside cities and towns and can be a backup water supply for the fast-growing communities of the lower east coast of Florida. The lake also supplies irrigation water for the expansive Everglades Agricultural Area, and is a critical supplemental water supply for the Everglades. Given these often competing demands on the lake, management of the water resource is a major challenge.

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History

The expansive lake is named Okeechobee, which means "big water" in the Seminole Tribe language. The lake had a large littoral (wetland) zone that extended from the Kissimmee River to the Florida Everglades, and a pelagic (open-water) zone much larger and deeper than that observed today. Before the late 1800s, the lake was largely unknown and considered just a myth by European settlers. Changes in south Florida have had severe impacts on Lake Okeechobee. In the 1890s, Hamilton Disston constructed a canal connecting Lake Okeechobee with Lake Hicpochee, the headwaters of the Caloosahatchee River. This provided the lake's first outlet to tidewater via the Caloosahatchee River. In the early 1900s, the Everglades Drainage District constructed several other canals that impacted Lake Okeechobee. The St Lucie, Hillsboro, North New River, West Palm Beach, and Miami canals were constructed from the lake to tidewater. These canals provided a slow, continuous drainage from Lake Okeechobee and the Everglades. The goal was to drain the northern Everglades for agriculture to prevent the crops from flooding.

During the 20th Century, much of the land around Lake Okeechobee was converted to agricultural use. To the north, dairy farms and beef cattle ranching became the major land uses, while in the south, sugar cane and vegetable farming increased rapidly. Small towns arose in this region, some very close to the lake. A small muck levee was constructed along the southern shore of the lake to protect those towns and farms. But then, in the 1920s two major hurricanes struck south Florida. One of them generated a storm surge in the lake that flooded coastal areas and hundreds of acres to the south and killed approximately two thousand people. To prevent this kind of devastation from recurring, the state asked Congress for help. The Congress directed the United States Army Corps of Engineers (USACE) to lead efforts to prevent future tragedies of that scale. Building the Herbert Hoover Dike, an earthen levee that still surrounds the lake's perimeter, was one of the first features of the Corp's solution.

Problem

As a result of the system of canals and levees built by the Corps and others, today, all discharges into and out of the lake are artificially controlled (except Fisheating Creek). One of the major impacts of the dike on Lake Okeechobee was to restrict the littoral zone to a much smaller region, along the western and southern shorelines. When water levels in the lake become very high, this reduced littoral zone now cannot expand outward. Instead, it is flooded with deeper and deeper water.

At the same time the dike and water control structures were completed, the Corps developed a regulation schedule that is cooperatively administered by the Corps and South Florida Water Management District (SFWMD). The Lake Okeechobee regulation schedule was designed to provide floodwater storage capacity during the wet season, and to supplement water supply during the dry season. The regulation schedule for the lake has been modified several times since implementation. Under these regulation schedules, and combined with several years of heavy rainfall events, the lake has experienced frequent and prolonged high water levels. These have been extremely damaging to both the lake and to downstream ecosystems. These high water levels led to drastic declines in the lake's submerged plant beds. Also, scientists at the Florida Fish and Wildlife Conservation Commission have documented substantial declines in the juvenile ages classes of important sport fish (such as bass).

When lake levels are particularly high, large freshwater flood control discharges are sent through canals to the St. Lucie and Caloosahatchee estuaries, impacting estuarine organisms and habitat. These freshwater discharges turn the brackish environment fresh and stress the marine organisms. If the freshwater discharges are large enough or long enough, the result maybe the mortality of these marine organisms.

Likewise, extremely low water levels during the dry season also can threaten the lake's ecological health by allowing certain exotic plants that have invaded the littoral zone to rapidly expand. Also during these times, water is kept in the lake for water supply, and the estuaries do not receive flow. At times the saline levels become too high in the estuaries. Low water levels and lack of flow may become a greater concern in the future when a greater water supply is needed for both Everglades restoration and the growing human population of south Florida.

<u>Development of WSE</u>

The traditional regulation schedules used for Lake Okeechobee resulted in prolonged periods of high water or low water. Neither of these situations were desirable from both the environmental and water supply standpoint. Following flood events in 1994 and 1995, the 1997 –1998 El Nino event demonstrated the need for further refinements to recover the health of Lake Okeechobee’s littoral zone. In July 2000, the previous regulation schedule was replaced with the “Water Supply and Environment” (WSE) schedule developed by the South Florida Water Management District in coordination with the Jacksonville District. WSE was designed in part based on the events of the 1997-1998 El Nino event that included the wettest dry season on 103 years of record available for the lake tributary basins. Like a traditional regulation schedule, WSE uses rule curves to guide water managers in deciding regulatory releases (Fig. 1). In addition to using current lake conditions, the WSE schedule incorporates “Decision Trees” which include examining tributary hydrologic conditions and seasonal and multi-seasonal climate outlooks. These Decision Trees are shown on Figure 2. Detailed analysis and computer simulations demonstrated that WSE’s performance is equal to or better than the previous regulation schedule for flood protection, water supply, and environmental objectives including the health of the lake ecosystem (U.S. Army Corps of Engineers, 1999a, 1999b).

Application of WSE

The WSE regulation schedule incorporates tributary hydrologic conditions and climate forecasts into the operational guidelines and is used in conjunction with the Operational Guidelines Decision Tree. The Decision Tree is divided into two parts. Part 1 defines Lake Okeechobee discharges south to the Water Conservation Areas (the everglades) and Part 2 defines Lake Okeechobee discharges to tidewater (the estuaries). The operational flexibility of the WSE schedule allows for adjustments to be made in the timing and magnitude of regulatory discharges based on conditions in the tributary basins and in the extended meteorological and climate outlooks. The Decision Tree provides essential supplementary information to be used with the WSE regulation schedule.

a. Tributary Hydrologic Conditions. The first diamond on the Decision Tree is "Tributary Hydrologic Conditions". Two measures of the hydrologic conditions are included with the design of the tree: (1) regional excess or deficit rainfall (rainfall minus evapotranspiration) for the past 30 days and (2) the average inflow for the past two weeks measured at S-65E on the Kissimmee River. As a conservative measure of flood protection the "wettest" of these two regional indicators is selected to represent the hydrologic conditions in the tributary basin. When considering drier than normal conditions, both indicators should indicate dry before the tributary hydrologic conditions are defined as "dry". Tributary hydrologic conditions are updated weekly.

b. Meteorological Forecast of up to 30 Days. The second diamond used during high lake stages (Zones B and C) for determining discharges to tide is the "Up to 30-day Meteorological Forecast". The season of the year as well as the lake level determine the most appropriate forecast to use. Shorter-range meteorologic and climatological forecasts (a few days up to 1 month) are the generally the most appropriate forecasts to use. These forecasts are developed by SFWMD meteorologists or NOAA.

c. Seasonal Climate Outlook. The third diamond is the "Seasonal Climate Outlook". With recent advances in climate prediction, it is now possible to predict, with some level of confidence, whether the upcoming season is likely to have above, below, or near-normal rainfall. The Climate Prediction Center (CPC) issues forecasts at this level of detail. These classifications are used for the expected net gain in storage or loss in the lake.   The CPC produces climate outlook for windows for a one-month window for the next month and 13 three-month overlapping windows going into the future, in one month increments. The climate outlooks are presented in maps and for each time period they give the probability of temperature and rainfall being in each of the three classifications described above.   In addition to the official CPC forecasts, several alternative methods can be used to determine the seasonal outlook. These include looking at historical net inflows into Lake Okeechobee. Several methods are used to produce the net inflow outlook including: (1) Croley's method (1996), (2) SFWMD empirical method (2000) and (3) other experimental forecast methods. As much as possible, all of the above methods should be used any time WSE requires a seasonal outlook in order to verify results and detect outliers. Croley's method uses historical monthly rainfall for the tributary basins into Lake Okeechobee (1914-1988), historical Lake Okeechobee net inflows (1914-1988), and the CPC outlook probabilities for rainfall. The SFWMD empirical method was developed as an alternative to Croley's method to utilize the information provided by the CPC when Croley's method yields no feasible solution.

d. Multi-seasonal Climate Outlook. The fourth diamond is the "Multi-seasonal Climate Outlook". The onset of hydrologic drought in Florida is often initiated with below normal rainfall during the wet season (May – October), which leads to lower availability of water supply for the upcoming dry season months (November – April). This is especially true if La Nina conditions develop in the Pacific Ocean during the winter months. On the other hand, above normal wet season rainfall often leads to the need for regulatory discharges from Lake Okeechobee during the same dry season. This latter event is especially crucial if an El Nino condition develops in the tropical Pacific during the winter months. With this understanding, the design of the WSE operational schedule included a multi-seasonal hydrologic outlook as one of the key decision criterion. This criterion is based on expected inflow during the remainder of the current hydrologic (wet or dry) season and the entire six-months of the next season. The multi-seasonal hydrologic outlook is therefore defined as either: (1) the remainder of the wet season and the upcoming dry season, or (2) the remainder of the dry season and the upcoming wet season. The last 1 or 2 months of a particular season are considered transition months. During these transitions, special rules are used in forming the multi-seasonal outlook if above-normal or below-normal rainfall is projected.

e. Flexibility. The operational flexibility of the WSE schedule allows for adjustments to be made in the timing and magnitude of Lake Okeechobee releases based on conditions in the Lake, in the tributary basins, conditions in downstream receiving water bodies and on extended meteorological and climate outlooks. These conditions are valuable for determining whether the appropriate window of opportunity exists to "hedge" water management practices by taking advantage of the recent advances in climate forecasting. For example, if climate outlooks indicate drought conditions are likely, no releases will be made; however, if wetter than normal conditions are indicated, water may be released. The decision criteria (diamond-shaped boxes) in the Decision Tree are the points from which to begin making operational decisions. Ultimately, water managers must synthesize this information and make the best operational decisions based on current and forecasted conditions. In addition, various departmental staff within the SFWMD provide technical input on a weekly basis, as needed, to supplement the WSE operating criteria. Estuarine, Everglades, and lake scientists monitor and report on rainfall effects, salinity conditions, bird-nesting success, tree island conditions, and water supply projections within the Lake Okeechobee system.

Conclusions

Use of traditional rule curves for Lake Okeechobee resulted in water management decisions that were reactive to climatic conditions. Regulatory discharges were initiated solely on the current lake stage. These rule curves provided a rigid course of action regardless of tributary hydrologic conditions or future climatic conditions. In other words, you could not manage the water until it was on the ground, or were forced to respond when there was no water and it was too late. This generally resulted in lake stages that were too high or too low. The lake went too high when releases started too late and hydrologic tributary conditions were wet due to excessive rainfall in the headwaters. The lake went too low when water supply demands outpaced available water resulting in a significant drop in lake stage.

While WSE is not a flawless regulation schedule, it has allowed water managers to be pro-active by using recent advances in climate forecasting. Water managers must now consider inflows, predicted future climatic conditions, conditions in downstream water bodies, as well as the current lake stage in deciding to initiate regulatory releases. This has resulted in a more balanced approach to water level management of Lake Okeechobee. While all the competing, and sometimes conflicting, demands on the lake will never be satisfied, WSE and its decision criteria will hopefully continue to improve conditions for the environment and water supply users while serving as the forerunner to future innovative advances in hydrologic forecasting, modeling, and analysis.

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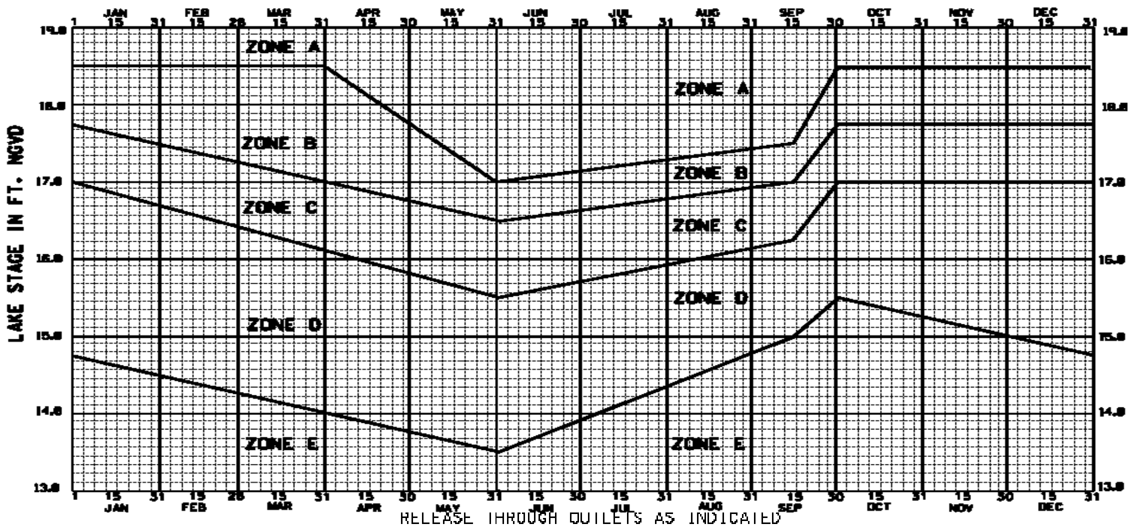

RELEASE THROUGH OUTLETS AS INDICATED

ZONE	AGRICULTURAL CANALS To WCAs (1,2)	CALOOSAHATCHEE RIVER AT S-77 (1,2,4)	ST. LUCIE CANAL AT S-80 (1,2,4)
A	PUMP MAXIMUM PRACTICABLE	UP TO MAXIMUM CAPACITY	UP TO MAXIMUM CAPACITY
B (3)	MAXIMUM PRACTICABLE RELEASES	RELEASES PER DECISION TREE (THESE CAN RANGE FROM MAXIMUM PULSE RELEASE UP TO MAXIMUM CAPACITY)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM MAXIMUM PULSE RELEASE UP TO MAXIMUM CAPACITY)
C (3)	MAXIMUM PRACTICABLE RELEASES	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 6500 CFS)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 3500 CFS)
D (3,5)	AS NEEDED TO MINIMIZE ADVERSE IMPACTS TO THE LITTORAL ZONE WHILE NOT ADVERSELY IMPACTING THE EVERGLADES. (SEE NOTE 5.)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 4500 CFS)	RELEASES PER DECISION TREE (THESE CAN RANGE FROM NO DISCHARGE UP TO 2500 CFS)
E	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE

NOTES:
(1) SUBJECT TO FIRST REMOVAL OF RUNOFF FROM DOWNSTREAM BASINS
(2) GUIDELINES FOR WET, DRY AND NORMAL CONDITIONS ARE BASED ON: 1) SELECTED CLIMATIC INDICES AND TROPICAL FORECASTS AND 2) PROJECTED INFLOW CONDITIONS. RELEASES ARE SUBJECT TO THE GUIDELINES IN THE WSE OPERATIONAL DECISION TREE, PARTS 1 AND 2.
(3) RELEASES THROUGH VARIOUS OUTLETS MAY BE MODIFIED TO MINIMIZE DAMAGES OR OBTAIN ADDITIONAL BENEFITS. CONSULTATION WITH EVERGLADES AND ESTUARINE BIOLOGISTS IS ENCOURAGED TO MINIMIZE ADVERSE EFFECTS TO DOWNSTREAM ECOSYSTEMS.
(4) PULSE RELEASES ARE MADE TO MINIMIZE ADVERSE IMPACTS TO THE ESTUARIES
(5) ONLY WHEN THE WCAs ARE BELOW THEIR RESPECTIVE SCHEDULES

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
LAKE OKEECHOBEE

DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
DATED: 5 NOVEMBER 1999

WSE (WITH CLIMATE OUTLOOK)

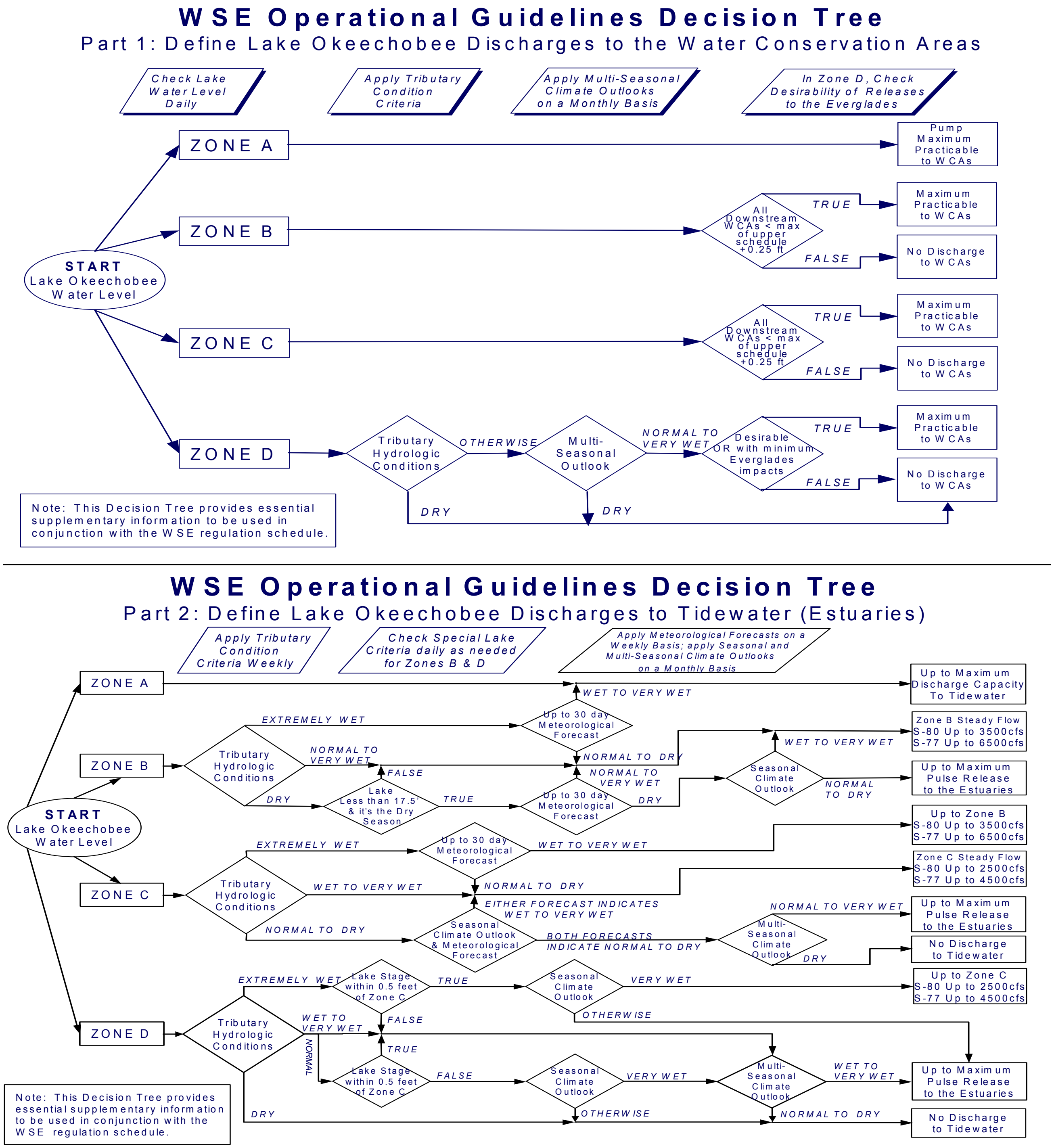

Figure 2 Operational Guidelines Decision Tree